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5th GOES Users' Conference: AIPS: The ABI Instrument Performance Simulation

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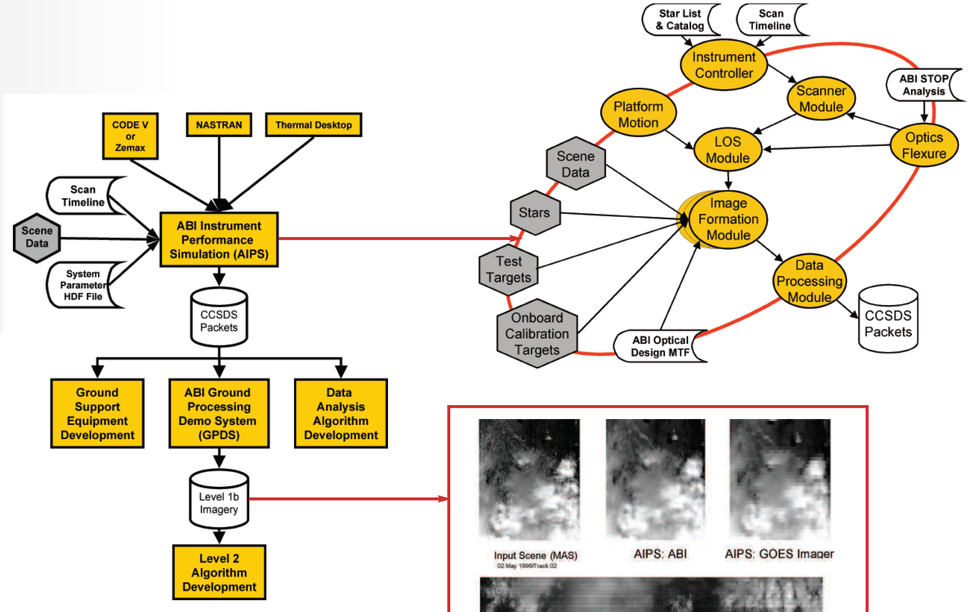
TOP-LEVEL OVERVIEW

AIPS generates radiometrically accurate image data and packages it along with the corresponding telemetry to form simulated ABI CCSDS data streams as part of the ABI end-to-end simulation. The context in which it operates is illustrated in the Figure to the right.

AIPS operation is driven by the same timelines that drive the ABI instrument. These timelines are a time-sequence of operations that instruct the instrument when to begin Earth swath, calibration, star, and space-look data collections. A configuration-controlled parameter spreadsheet serves as the definitive set of parameters for the System and Design Engineers. The ABI instrument parameters are read from an HDF file that is automatically generated from this spread-sheet. This simplifies running the simulation and eliminates parameter errors.

Output generated by an optical design program and the Structural-Thermal-Optical Performance (STOP) analysis is fed into AIPS from data files. This allows the end-to-end simulation to incorporate the fidelity of the subsystem simulations without adding to the complexity of the system-level simulation.

Unlike many instrument simulations, AIPS provides more than simulated imagery. AIPS output consists of a CCSDS packet stream that conforms to the ABI-to-Spacecraft ICD. It includes telemetry packets in addition to the detector samples of Earth and calibration scenes. This data format permits the AIPS output to be directly ingested into the Ground Processing Demonstration System (GPDS) and the GSE test set, bypassing the need for real instrument data in order to test the data handling software and algorithms.



EXTENSIBLE ARCHITECTURE

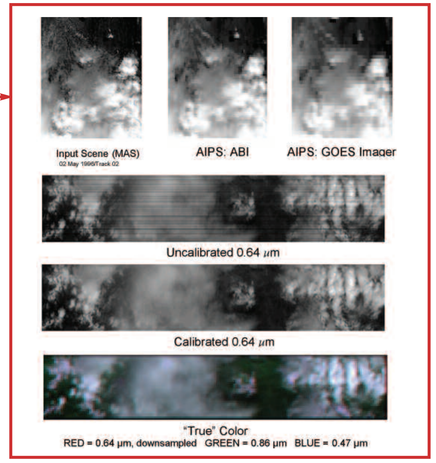
AIPS is built on the Message Passing Interface (MPI) protocol. MPI is an open-source standard for implementing distributed-processing applications.

A simple topology configuration file specifies the distribution and interconnection of simulation modules across the nodes of the computation cluster. Upon launching AIPS in the MPI environment, each process reads the topology file, launches its own simulation processing objects, and establishes the logical connections to the other processing objects to which it will be receiving or sending data. The topology can be changed through the topology configuration file without any modification to the software that implements the simulation processing objects. This allows the simulation to be spread across any number of processors that may be available. It also allows easy customization of the simulation for various applications.

AIPS modules and system parameters are all organized hierarchically in a manner that follows a functional decomposition of the ABI system. Consequently, there is a direct mapping between the ABI hardware and requirements and the AIPS modules.

This facilitates:

- Verification and validation of AIPS performance
- Verification of the flowdown of system specifications
- Extensibility to other systems by substituting new modules
- Adding new modules and parameters to increase fidelity



USES

AIPS is essentially a low cost, low risk EDU. Instrument time is precious, and comes late in the program schedule. It is neither efficient nor cost-effective to wait for real instrument data in order to start testing ground processing algorithms, data analysis algorithms, and the Test Set software. AIPS provides data needed to test all of these things and wring out any issues before the ABI hardware goes into system test. Thus issues that would have otherwise gone undetected will be solved before they have a chance to interrupt the test flow and cause schedule delays.

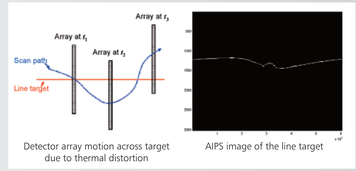
GPDS is required to demonstrate GP data latency. To be credible, GPDS must be fed data at the same rate that it is provided by the real instrument. The CCSDS stream format of the AIPS output facilitates this.

Algorithms used to analyze System Level Test data and the implementations of those algorithms need to be verified and validated. AIPS provides simulated data that is as close to the real ABI data in terms of radiometry as is possible, permitting determination in advance that algorithms will provide the evidence needed to demonstrate spec compliance. This will eliminate surprises that could happen during test that would cause schedule delays.

AIPS data will also be used to test the Ground Support Equipment interfaces and data handling. This will ensure that there is a common understanding of the ICDs and it will avoid delays due to bugs that could have cropped up during test.

FEATURES

Imaging system simulations operate in either image-space or spatial frequency-space. AIPS operates in image-space in order to permit implementation as a time-based simulation. While this significantly increases run times, it allows a more accurate simulation of scanning artifacts and radiometry. It also facilitates the testing of control and compensation algorithms, and the generation of simulated data streams.



Detector array motion across target due to thermal distortion

AIPS image of the line target

The AIPS LOS model is a high fidelity simulation of the LOS motion that includes scan mirror motion (driven by a scan timeline), spacecraft motion, jitter, and thermal distortion. The GEO environment is a challenging one in which to model LOS motion for two reasons. First, the solar heat load is constantly changing throughout the orbit, causing thermal distortion of the observatory that produces a time-varying LOS displacement. While the instrument is designed to minimize thermal effects, there is some residual motion. Second, with the long ranges to the Earth's surface from GEO, the pointing accuracy and pointing determination requirements are very small, on the order of a few microradians. Thus the LOS must be modeled with a correspondingly high accuracy.

We achieve this by using the motion of instrument components calculated by the STOP analysis to drive the AIPS LOS calculations. An illustration of the thermal effects on the LOS is presented in the Figure above. For this case, we have scanned a horizontal line target and altered the time scale so that thermal distortion that would normally happen over a 24 hour period occurs within the time of a scan of a single swath.

The AIPS radiometric model is a high fidelity simulation of the optical response (spatial and spectral) of the system, the electronic response of the system, and the precise LOS at the time of sample collection. It models the spatial response function of the entire system (platform motion, instrument effects, and processing effects) and uses it to sample the input image data. Special care has been used to ensure that the proper signal is calculated when the LOS falls between samples of the input scene. We developed sampling methods that avoid any sampling artifacts that would not be present in the real system. This method produces the proper signal when sampling the input data at the exact LOS position, even when it falls between input scene samples. The radiometric model also includes all of the relevant gain, offset, and noise terms for the ABI system.

AIPS implements the instrument scan control and motion compensation algorithms in AIPS. Thus AIPS has effectively served as a testbed, resulting in refinement and verification of these algorithms and their documentation.

The Data Processing module digitizes and compresses the data and packetizes it using the CCSDS protocol. Scene and telemetry packets are multiplexed and then written to a disk file. Types of packets are Instrument Configuration, Detector Masks, Housekeeping, Scan Telemetry, Spacecraft position and attitude telemetry, Science Data, Earth scene, Star, Space, Calibration target.

IMAGE RESULTS

Sample AIPS imagery was generated from Modis Airborne Simulator (MAS) imagery. The first set of three images to the left compares the original MAS image with the corresponding ABI 0.64 channel image and current GOES imager visible channel image. The GOES imager was simulated by simply changing parameter values without the need for altering the code.

The next set of three images depicts uncalibrated AIPS imagery (showing striping due to variations in detector characteristics), the results of running AIPS data through the calibration algorithm, and a "truecolor" image. Note that the 0.64 channel has a higher spatial resolution than the 1.61 channel, so it was downsampled using the algorithm developed for ABI prior to combining the channels. The NIR channel has been substituted for a non-existent green channel for this image.

ITT Corporation. The Advanced Baseline Imager (ABI) is a NOAA funded, NASA administered meteorological instrument program. This poster does not reflect the views or policy of the GOES-R Program Office.